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UNITED STATES ARMY
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13. ABSTRACT

A study was conducted to determine the effect of irradiation dose from a cobalt-60 source with respect to irradiation temperature on the thiamine content of ham. In addition, thermal sterilizing (F_0) values ranging from 0.0 to 1.0 in 0.2 increments were determined for ham in respect to its thiamine content for comparison with radiation sterilizing doses for ham. The products selected for testing were fully-cooked smoked ham, pasteurized-cooked canned ham, and thermally processed commercially-sterile canned ham. The irradiation was performed at three different irradiation levels (3.0 to 4.0, 4.5 to 5.6, 6.0 to 7.5 Mrad) at five different temperatures (+5° ± 5°; -20°, -40°, -60°, and -80°C ± 10°C). The results show that as the temperature of irradiation was decreased, thiamine retention was increased. Furthermore, as the irradiation dose was increased, the thiamine content was decreased. During heat treatment of cured ham at an F_0 value of 0.2, there was a 30% loss of thiamine. An additional 5 to 10% decrease in thiamine content took place at F_0 values from 0.4 to 1.0.

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FOREWORD

No food preservation method is uniformly superior for all foods. Food technologists and those in associated scientific or engineering disciplines strive constantly to improve and refine food processing methods in current use, and to expand their use to additional food items, thereby improving in some manner the quality of our food supply. Before a major change in a food processing method can be fully accepted for universal use, its impact upon food attributes - including nutrient content - should be assessed. Patently, an innovation must not result in nutritional detriment to the individual when food processed by the altered method is consumed. Ideally, the new method will result in a nutritionally superior product.

Preservation of food by ionizing radiation is a relatively recent concept compared to established processing methods. As such, it is essential that thorough knowledge of its effect upon the nutritional quality of food be established.

This report deals with the effect of irradiation upon the thiamine content of ham. Pork products are much higher in thiamine than other commonly used meat products. On a unit-weight basis, ham contains approximately ten times as much of this vitamin as does beef round. No such differences exist in respect to other vitamins. Since pork products are important dietary sources of thiamine in this country, it became necessary to determine the effect of irradiation dose and temperature upon the retention of this vitamin for use in obtaining acceptance of ionizing energy as a process for sterilizing ham for human consumption.

The work reported was conducted under Project No. 1J062110A033.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

A study was conducted to determine the effect of irradiation dose from a cobalt-60 source with respect to irradiation temperature on the thiamine content of ham. In addition, thermal sterilizing (F_o) values ranging from 0.0 to 1.0 in 0.2 increments were determined for ham in respect to its thiamine content for comparison with radiation sterilizing doses for ham. The products selected for testing were fully-cooked smoked ham, pasteurized-cooked canned ham, and thermally processed commercially-sterile canned ham. The irradiation was performed at three different irradiation levels (3.0 to 4.0, 4.5 to 5.6, 6.0 to 7.5 Mrad) at five different temperatures (+5° ± 5°C -20°, -40°, -60°, and -80°C ± 10°C). The results show that as the temperature of irradiation was decreased, thiamine retention was increased. Furthermore, as the irradiation dose was increased, the thiamine content was decreased. During heat treatment of cured ham at an F_o value of 0.2, there was a 30% loss of thiamine. An additional 5 to 10% decrease in thiamine content took place at F_o values from 0.4 to 1.0.

INTRODUCTION

All food preservation methods reduce the nutritive value of foodstuffs to some degree, and the preservation of food by exposure to ionizing energy is no exception. Since pork products, when consumed, make a significant contribution to the daily food thiamine intake, it was more than of academic interest to determine the extent of thiamine loss which occurs during irradiation. A study was conducted to determine the extent of the thiamine loss which occurs in ham during irradiation under various specified conditions.

The specific purpose of this study was to investigate the effects of irradiation dose from a Co^{60} source with respect to irradiation temperature on the thiamine content of ham. Additionally, provision was made to determine the thermal sterilizing (F_9) values for ham with reference to its thiamine content for comparison with radiation sterilizing values for ham.

PROCEDURE

Three products were selected for study, as follows:

A. Smoked, skinless, boneless, cured, rolled, fully-cooked ham (internal temperature 67-69°C; no added substance);

B. Non-smoked, skinless, boneless, cured, pasteurized-cooked, canned ham (with gelatin added) and;

C. Thermally-processed, commercially-sterile ham.

The experimental plan is given in Table 1. The products were processed both as whole ham and as ground ham. The ground product was included to reduce variability in proximate composition, thiamine content and processing effects among replicate samples. The irradiation of whole ham was performed at -20°, -30°, and -40°C ± 10°C at 4.5 to 5.5 Mrad. For the ground ham, three different irradiation levels (3.0 to 4.0, 4.5 to 5.6, 6.0 to 7.5 Mrad) were utilized, at each of five different temperatures (+5° ± 5°C and -20°, -40°, -60° and -80°C ± 10°C). The whole ham was cut into chunks and placed in 404 x 700 cans (2 lbs, 12 oz. ham per can) and brought to the process temperature prior to irradiation. The other samples were ground, put into 404 x 309 cans (1 lb, 6 oz. ham per can) and brought to the process temperature before irradiation.

The thermally-processed product was commercially prepared in oval-shaped, 1-1/2 lb. cans. The sterile process used by the meat processor is not known. However, it is considered to be in the range of F_o 0.2 to 0.4. Our laboratory heat-treated raw, cured, ground ham in 404 x 309 cans was processed to F_o values ranging from 0.0 to 1.0 in increments of 0.2.

All samples - irradiated and their non-irradiated controls, thermally-processed and their appropriate controls - were frozen (-29°C) after the processing treatment and held frozen until time of analyses. Five replicates for each variable were analyzed in duplicate for moisture, fat, salt (1), and thiamine (2) content by a contractor (Shankman Laboratories, Los Angeles, Cal.). Before analyses, all ground ham samples were remixed and the whole ham samples were ground and thoroughly homogenized. Juices, when present, were discarded before grinding. The values reported represent the average of five replicates analyzed in duplicate and corrected for their individual moisture, fat, and salt contents.

RESULTS AND DISCUSSION

The results on whole, fully-cooked, smoked ham irradiated at 4.5 to 5.6 Mrad show that as the temperature during irradiation decreased from -20° to -40°C, thiamine retention increased from 25 to 44 percent (Table 2). When whole, pasteurized-cooked, ham was irradiated at the same dose, higher thiamine retention was also obtained at -40°C (Table 3) than at -20°C. The calculated and observed points are shown in Figure 1. The slopes are parallel for the two products, the fully-cooked, smoked ham being slightly superior.

Data obtained from analyses of fully-cooked, smoked, ground ham irradiated at various doses and each dose at five different temperatures corroborate those obtained with the whole ham. As indicated previously, the ground product was used to reduce variability in proximate composition, thiamine content, and processing effects among replicate samples. Tables 4-6 demonstrate that when the dose is held constant and the temperature is decreased, the thiamine retention is increased. It should be pointed out that, as expected, the deviation among replicates was less for ground than for whole samples of ham. The data in the three previous tables are summarized in Table 7 which clearly shows that the best retention of thiamine was obtained at the lowest irradiation temperature. Furthermore, as the irradiation dose increased, the thiamine content decreased at corresponding irradiation temperatures. Attention is directed to the poor retention of thiamine at +5°

± 5°C, irrespective of the irradiation level. Little or no difference in thiamine retention occurred between irradiation at -40° and -60°C at the two highest dose levels. Regression analyses (Fig. 2) show that the slopes vary with the treatment.

Pasteurized-cooked, ground ham irradiated at 4.5 to 5.6 Mrad at several temperatures (Table 8) follows the same pattern as fully-cooked, smoked, ground ham treated similarly. Again, there was no difference in thiamine retention between irradiation at -40° and -60°C, and the pasteurized samples appeared to retain less thiamine than the fully-cooked, smoked sample receiving comparable treatment. A comparison of thiamine destruction in ham irradiated at 4.5 to 5.6 Mrad is given in Figure 3.

The effect of curing and thermal processing on the thiamine content of ham is given in Table 9. In the curing process, approximately 80% of the thiamine from the raw product was retained. During the heat treatment, based on the thiamine content of the raw, cured product, there was 70% retention of thiamine at an F_o value of 0.2. At F_o values from 0.4 to 1.0, an additional 5 to 10% decrease of thiamine took place. If one assumes that the thermally-processed, commercially-sterile ham was made from a raw, cured product like the one in this study then 64% of the thiamine was retained.

At this writing, the thermally-processed, commercially-sterile, canned ham used in this study represents the commercial product which would be replaced by an irradiated product sterilized with 3.0 - 4.0 Mrads at -30°C ± 10°C. Since the commercial sample utilized in this study does not originate from the same starting material as the irradiated samples, no direct comparisons with these data can be made. However, the products are equivalent if one compares the thiamine retention in fully-cooked, smoked, ground ham irradiated with either 3.0 to 4.0 or 4.5 to 5.6 Mrad at -40° to -80°C ± 10°C with cured, ground ham thermally sterilized with F_o values of 0.4 to 0.6 (Table 10), which are the typical F_o values for thermal processing of commercially-sterile canned hams.

SUMMARY

A study was conducted to determine the effect of irradiation dose and temperature on the thiamine content of fully-cooked, smoked and pasteurized-cooked, canned ham. The irradiation dose levels employed were 3.0 to 4.0, 4.5 to 5.6, and 6.0 to 7.0 Mrad. The temperatures utilized were +5° ± 5°C; -20°, -30°, -40°, -60° and -80°C ± 10°C. The results show that the retention of thiamine was decreased with an increase in irradiation dose. The retention of thiamine was increased as the temperature of irradiation was decreased.

TABLE 1

Experimental Design

Form	Product Treatment: Dose (Mrad)	Product Treatment: Temperature °C ± 10°C
Smoked, Skinless, Boneless, Cured, Rolled, Fully-Cooked Ham (Internal Temperature 67-69°C; No Added Substance)		
Whole	None	Held Frozen[1]
Whole	4.5 to 5.6	-20°, -30°, -40°
Ground	None	Held Frozen
Ground	3.0 to 4.0	+5° ± 5°, -20°, -40°, -60°, -80°
Ground	4.5 to 5.6	+5° ± 5°, -20°, -40°, -60°, -80°
Ground	6.0 to 7.5	+5° ± 5°, -20°, -40°, -60°, -80°
Non-Smoked, Skinless, Boneless, Cured, Pasteurized-Cooked, Canned Ham (With Gelatin Added)		
Whole	None	Held Frozen
Whole	4.5 to 5.6	-20°, -30°, -40°
Ground	None	Held Frozen
Ground	4.5 to 5.6	+5° ± 5°, -20°, -40°, -60°, -80°
Raw, Cured, and Thermally-Processed Commercially-Sterile Ham		
Whole (1-1/2 lbs)	None	Held Frozen
Ground, raw	None	Held Frozen
Whole, Raw, Cured	None	Held Frozen
Ground, Raw, Cured	None	F_o0, $F_o0.2$, $F_o0.4$, $F_o0.6$, $F_o0.8$, $F_o1.0$

1 - Until analyzed

TABLE 2

Effect of Irradiation Temperature at 4.5 to 5.6 Mrad on the Thiamine Content of Whole, Fully-Cooked, Smoked Ham

Temperature °C ± 10°	Thiamine[1] mg/100 gms	Thiamine[1] Average Retention Percent
Control	3.99 ± 1.46[2]	
-20°	1.01 ± 0.63	25
-30°	0.77 ± 0.31	19
-40°	1.75 ± 0.58	44

[1] Values represent duplicate analyses on five replicates and have been corrected for their moisture, fat, and salt contents.

[2] Mean plus or minus standard deviation

TABLE 3

Effect of Irradiation Temperature at 4.5 to 5.6 Mrad on the Thiamine Content of Whole, Pasteurized-Cooked Ham

Temperature °C ± 10°	Thiamine[1] mg/100 gms	Thiamine[1] Average Retention Percent
Control	4.06 ± 0.45[2]	
-20°	0.30 ± 0.10	7
-30°	1.27 ± 0.14	31
-40°	1.27 ± 0.16	31

[1] Values represent duplicate analyses on five replicates and have been corrected for their moisture, fat, and salt contents.

[2] Mean plus or minus standard deviation

TABLE 4

Effect of Irradiation Dose and Temperature on Thiamine Content of Smoked, Skinless, Boneless, Cured, Rolled, Fully-Cooked, Ground Ham

3.0 to 4.0 Mrad

Temperature °C ± 10°	Thiamine[1] mg/100 gms	Average Retention Percent
Control	3.67 ± 0.39[2]	
+5° ± 5°	0.33 ± 0.03	9
-20°	1.94 ± 0.05	53
-40°	2.91 ± 0.22	79
-60°	3.21 ± 0.19	87
-80°	3.40 ± 0.14	93

[1] Values represent duplicate analyses of five replicates and have been corrected to their moisture, fat, salt-free basis.

[2] Mean plus or minus standard deviation.

TABLE 5

Effect of Irradiation Dose and Temperature on Thiamine Content of Smoked, Skinless, Boneless, Cured, Rolled, Fully-Cooked, Ground Ham

4.5 to 5.6 Mrad

Temperature °C ± 10°	Thiamine[1] mg/100 gms	Average Retention Percent
Control	3.67 ± 0.39[2]	
+5° ± 5°	0.22 ± 0.04	6
-20°	1.72 ± 0.18	47
-40°	2.38 ± 0.08	65
-60°	2.46 ± 0.10	67
-80°	2.97 ± 0.11	81

1 Values represent duplicate analyses of five replicates and have been corrected to their moisture, fat, salt-free basis.

2 Mean plus or minus standard deviation

TABLE 6

Effect of Irradiation Dose and Temperature on Thiamine Content of Smoked, Skinless, Boneless, Cured, Rolled, Fully-Cooked, Ground Ham

6.0 to 7.5 Mrad

Temperature °C ± 10°	Thiamine[1] mg/100 gms	Average Retention Percent
Control	3.67 ± 0.39[2]	
+5° ± 5°	0.13 ± 0.01	4
-20°	0.75 ± 0.18	20
-40°	1.85 ± 0.26	50
-60°	1.93 ± 0.06	52
-80°	2.73 ± 0.07	74

1 Values represent duplicate analyses of five replicates and have been corrected to their moisture, fat, salt-free basis.

2 Mean plus or minus standard deviation

TABLE 7

Summary of Effect of Irradiation Dose and Temperature on Thiamine Retention in Fully-Cooked, Smoked, Ground Ham

Temperature °C ± 10°	Dose (Mrad)		
	3.0 - 4.0	4.5 - 5.6	6.0 - 7.5
+5° ± 5°	9	6	4
-20°	53	47	20
-40°	79	65	50
-60°	87	67	52
-80°	93	81	74

TABLE 8

Effect of Irradiation Temperature at 4.5 to 5.6 Mrad on the Thiamine Content of Pasteurized-Cooked, Ground Ham

Temperature °C ± 10°	Thiamine[1] mg/100 gms	Thiamine[1] Average Retention Percent
Control	3.71 ± 0.18[2]	
+5° ± 5°	0.10 ± 0.01	3
-20°	0.76 ± 0.07	20
-40°	1.53 ± 0.07	41
-60°	1.53 ± 0.08	41
-80°	2.02 ± 0.12	54

[1] Values represent duplicate analyses of five replicates and have been corrected to their moisture, fat, salt-free basis.

[2] Mean plus or minus standard deviation

TABLE 9

Effect of Thermal Sterilization on the Thiamine Content of Ham

Product	Treatment	Thiamine[1] mg/100 gms	Average Retention Percent	
Raw, Uncured Ham	None	5.38 ± 0.15[2]	100	
Raw, Cured Whole Ham	Cured	4.16 ± 0.99	77	
Raw, Cured Ground Ham	F_o0.0	4.31 ± 0.08	80	100
	F_o0.2	3.04 ± 0.14		70
	F_o0.4	2.71 ± 0.29		63
	F_o0.6	2.83 ± 0.30		66
	F_o0.8	2.78 ± 0.21		64
	F_o1.0	2.54 ± 0.11		59
Thermally Sterilized[3]	--	2.66 ± 0.32		

1 Values represent duplicate analyses of five replicates and have been corrected to their moisture, fat, salt-free basis.

2 Mean plus or minus standard deviation

3 Commercial product

TABLE 10

Comparison of Thiamine Retention in Fully-Cooked Smoked, Ground, Irradiated Ham with Cured, Ground, Thermally-Sterilized Ham

	Method of Processing			
	Irradiation		Thermal	
	Mrad			
Temperature	3.0 - 4.0 Retention (%)	4.5 - 5.6	F_o	Retention (%)
-40°C ± 10°	79	65	0.4	63
-60°C ± 10°	87	67	0.6	66
-80°C ± 10°	93	81		

FULLY-COOKED, SMOKED —— O
PASTEURIZED, COOKED - - - □

$$y = \bar{y} + b\,(x - \bar{x}) \text{ where}$$
$$b = \frac{\Sigma xy - \Sigma x \Sigma y/n}{\Sigma x^2 - (\Sigma x)^2/n}$$

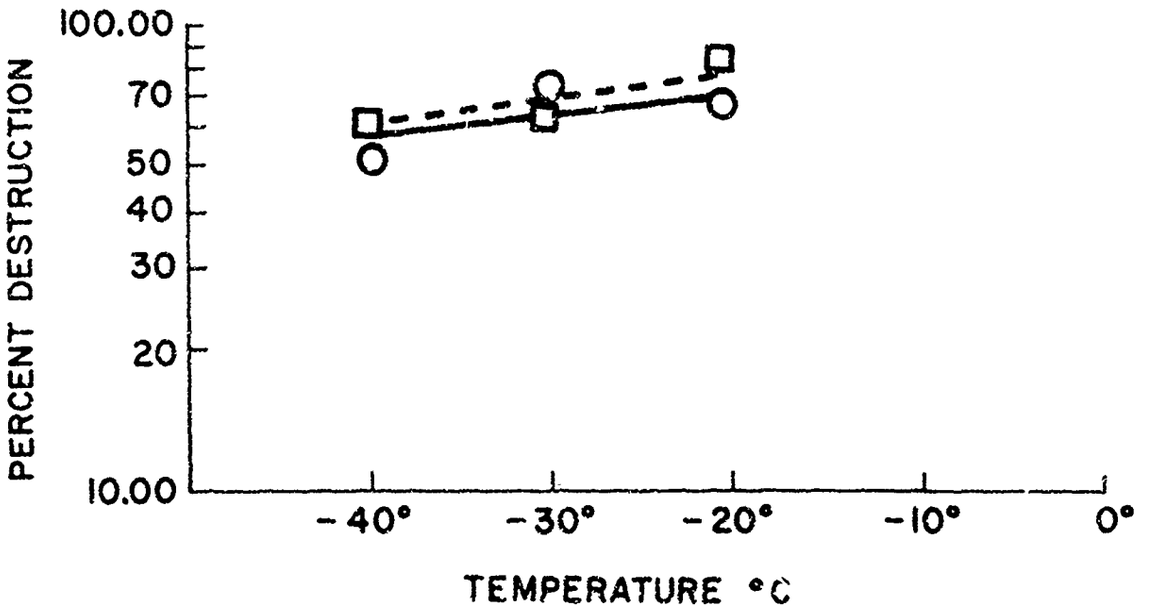

FIGURE 1. COMPARISON OF THIAMINE DESTRUCTION IN WHOLE HAM IRRADIATED WITH 4.5 TO 5.6 MRAD AT VARIOUS TEMPERATURES

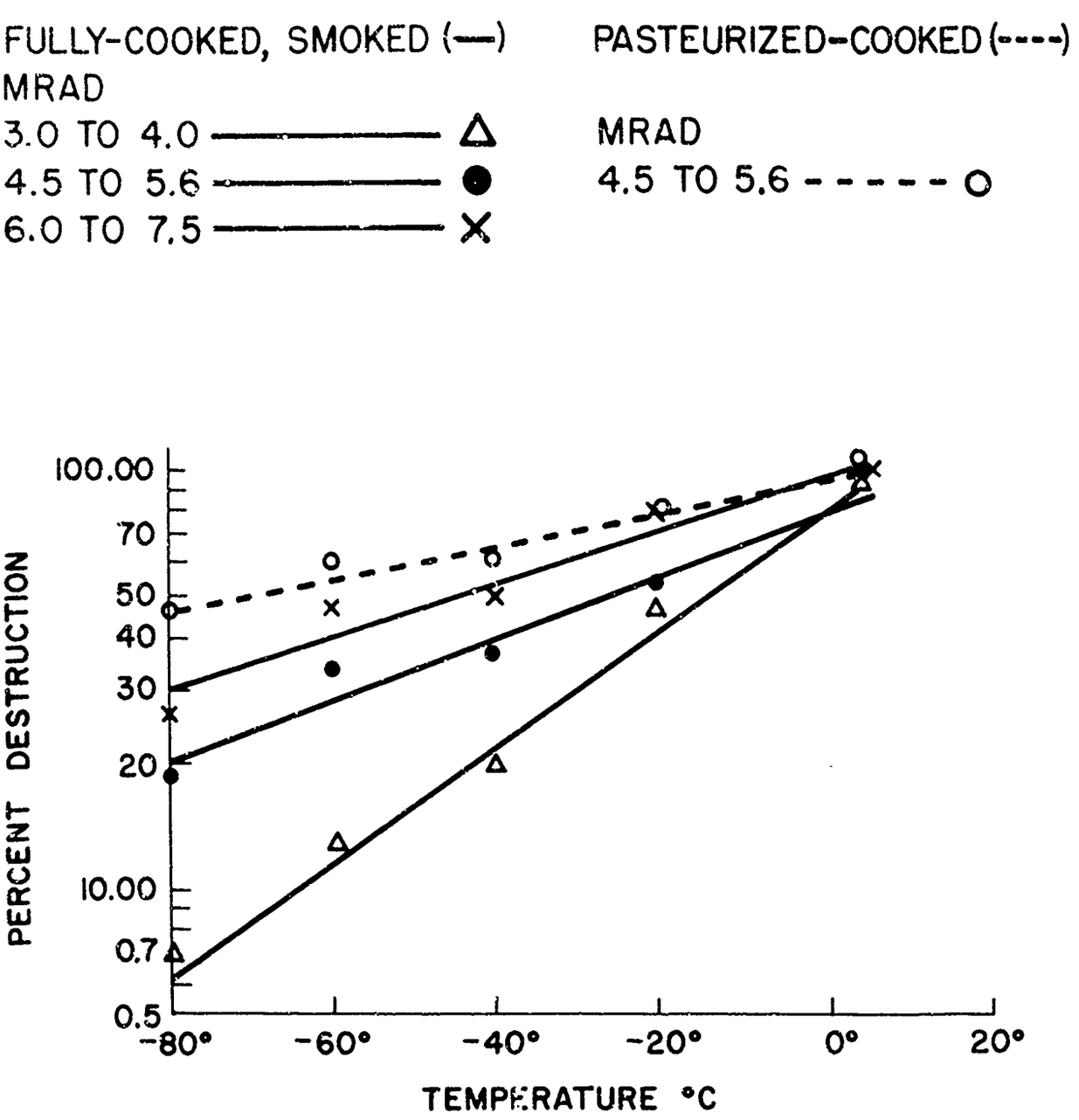

FIGURE 2. COMPARISON OF THIAMINE DESTRUCTION IN GROUND HAM IRRADIATED AT VARIOUS DOSES AND TEMPERATURES

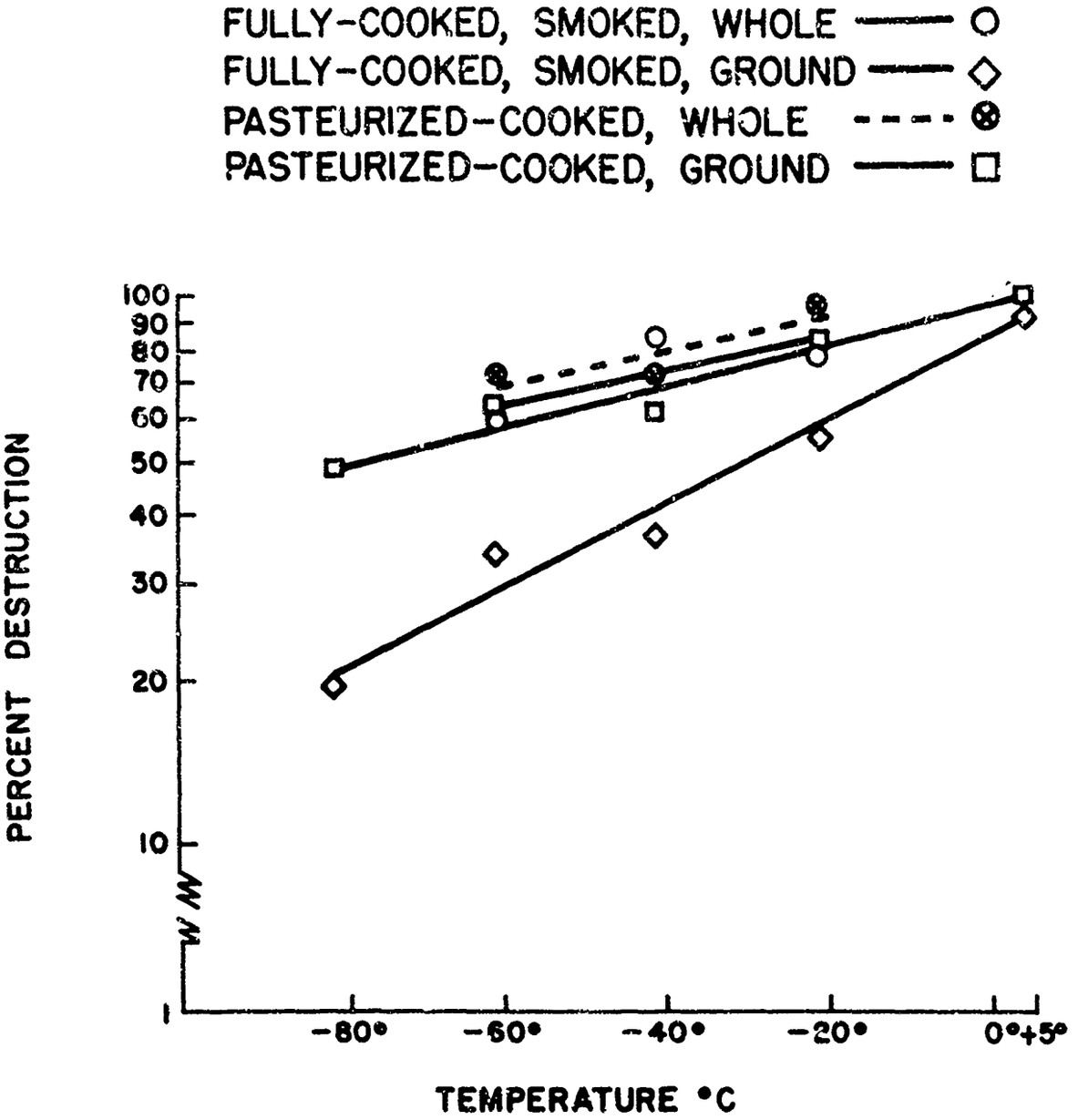

FIGURE 3. COMPARISON OF THIAMINE DESTRUCTION IN HAM IRRADIATED AT 4.5 TO 5.6 MRAD AT VARIOUS TEMPERATURES

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